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ROSAT Detection and High Precision Localization of X-ray Sources in the November 19, 1978 Gamma-Ray Burst Error Box

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ABSTRACT

We report on observations of the 1978, November 19 Gamma-Ray Burst source, performed with the ROSAT X-ray HRI experiment. Two sources were detected, one of which is possibly variable. The latter source is identical to the source discovered in 1981 by the EINSTEIN satellite, and recently detected by ASCA. The precise localization of these sources is given, and our data are compared with optical, radio and previous X-ray data.

Subject headings: gamma-rays: bursts

1. Introduction

Gamma-Ray Bursts (hereafter GRBs) were discovered some 25 years ago, and their origin remains enigmatic. Current data and models involve objects at distances ranging from several hundred of kiloparsecs to cosmological distances, an uncomfortable ignorance factor of at least 10^6 (see e.g. Lamb, 1995, Paczyński, 1995 and following papers for a discussion

on the GRB distance scale). Two approaches have been used to solve this problem, namely 1) the use of the logN - logS relation combined with the angular distribution of GRBs, and 2) the search for counterparts at other wavelengths, either quiescent or transient.

The first X-ray counterpart searches were done with the Einstein satellite. Five GRB small error boxes were observed (Pizzichini et al., 1986). This resulted in only one marginal, 3.5σ detection (Grindlay 1982) in the case of GRB 781119. Later, other observations were performed with the EXOSAT (Boër et al., 1988, 1991) and ROSAT satellites (Boër et al., 1993a, 1993b, Greiner et al., 1996), resulting in only one other possible candidate, that of the GRB 960501 source (Hurley et al. 1996a). In this last case, the source is seen at low galactic latitude, is heavily absorbed, and is possibly extragalactic.

The error box of GRB 781119 is one of the smallest known with a size of 8 arcmin^2 (Cline et al. 1981). It was observed at various wavelengths and a possible counterpart was found in X-rays in 1981 as mentioned above. A radio source was found at this position (Hjellming & Ewald 1981). Using archival data, Schaefer (1981) found an optical transient object with a position marginally compatible with the X-ray object, but its reality was questioned (Zytkow 1990; Greiner et al., 1990; see however Schaefer 1990). In addition, two possible emission lines have been found in the spectrum of GRB 781119 at 420 and 470 keV (Teegarden & Cline1980).

The error box of GRB 781119 was reobserved by Boër et al. (1988) in 1983 in order to confirm the EINSTEIN detection with the EXOSAT satellite. The source was not detected, and the 3σ upper limit on the flux was 1.2×10^{-12}erg.cm^{-2}.s^{-1}, for a T = 10^6K blackbody spectrum. This limit was consistent with the EINSTEIN detection for a 10^6K blackbody source at a distance $\geq$ 2kpc. On the other hand, the EINSTEIN source, detected at a 3.5σ level, might have been a variable source, or, alternatively, a statistical fluctation. In order to settle the question, we observed the region in 1995 with the ROSAT satellite. Because of a technical problem, the observation was interrupted and rescheduled in 1996. Independently, the same source was observed by Hurley et al. (1996b) using the ASCA satellite.

We report here on the observations carried out by ROSAT, which are compared with the ASCA observation and data acquired at other wavelengths. The observation resulted in the detection of two objects in the error box in 1996, one of them present in the 1995 observation, possibly variable, and probably associated with the EINSTEIN source. The other is probably the X-ray counterpart of a quasar.

2. Observations and Results

The ROSAT X-ray telescope was used with the HRI detector. The total energy range is 0.2 - 2.5 keV, with 2 arcsec spatial resolution and no energy resolution. The data were processed using the EXSAS and MIDAS data analysis software packages. The first observation was carried out on January 10, 1995, for a total of 2481 seconds effective time, and the second period of observations lasted from December 21st, 1995, till January 11th, 1996 for a total of 40776 seconds duration time. The observations are summarized in Table 1. In the GRB error box, one object was detected during the 1995 observation, and two objects in 1996. A SIMBAD cross-identification of the HRI field of view showed that two cataloged sources are detected in X-rays: QSO 0116-288, and QSO 0117-2837.

The best position for object #1 (detected in both the 1995 and 1996 observations) is $\alpha = 1h18m49.6s$, $\delta = -28 \deg 35'53"$(equinox 2000.0), and for object #2 $\alpha = 1h18m47.4s$, $\delta = -28 \deg 35'45"$, with an error radius of 10 arcsec (Briel et al., 1994) . These positions were computed using the 1996 observation only. As indicated in table 1, there are some marginal indications that the flux of object #1 varied by a factor of ≈ 2 between 1995 and 1996, while no evidence for variability was found during the 1996 observation. However, if we look at the flux over an extended period, assuming a constant spectrum for the source, long term variability is clearly implied from the non-detection by the EXOSAT satellite (Boër et al., 1988). The non detection of object #2 in 1995 is consistent with its flux in 1996. The 3σ upper limit to the count rate for object #2 in January 1995 is 4.6×10^{-3} c/s. No variability has been found in the 1996 data for this object.

3. Discussion

Figure 1 displays the ROSAT HRI image from the observation of 1996. We show the EINSTEIN (Grindlay et al., 1982), ASCA (Hurley et al. 1996b) and ROSAT error boxes, as well as the radio sources present in the GRB 781119 error box (Hjellming and Ewald 1981). There are two HRI sources in the GRB 781119 error box. Object #2 may be identified with the quasar QSO 0116-288 whose catalog position is only 4 arcsec from the ROSAT position. Object #1 is the closest to the EINSTEIN error box and may be identified with the radiosource Q of Hjellming and Ewald (1981). This source is however slighty outside the 90% confidence EINSTEIN error box, but the low level of confidence (3.5σ) of the EINSTEIN detection may introduce some additional uncertainties in its confidence region. In addition, the proximity of the HRI 10 arcsec. error box and the EINSTEIN error box is probably compatible with the possibility that the ROSAT source is in the 99% EINSTEIN error box.

More interesting is the fact that the ROSAT source may be variable. Its flux varied by a factor larger than 2 within roughly one year, though the uncertainty in the first (January 1995) observation is large. In addition there is some evidence for variability between the ASCA observation (Hurley et al. 1996b), and the present data, and a clear discrepancy with the EXOSAT observation, which can only be explained by variability . On the other hand, there is no evidence for variability in the data taken by ROSAT during the period December 21st, 1995 - January 11th, 1996. Hence we deduce that the object #1 is variable over the long term (i.e. $\geq$ 1y). Because of the lack of spectral resolution of the ROSAT HRI instrument, we were unable to investigate whether this variability is also present in the source spectra.

Thanks to the high precision of the localization given by the ROSAT HRI instrument, we can reanalyze data taken in 1981 - 1982 at ESO (Pedersen et al. 1983), as well as more recent, unpublished observations. The sum of several unfiltered exposures is displayed in figure 2. The uncertainty circles for objects #1 and #2 are also displayed. A detailed study of the optical data and of the optical variability of the objects near the ROSAT sources is reported by Pedersen (1996). From archival data taken by Pedersen et al. (1983) we estimate the R, V, and B magnitudes of object #2 to be respectively $\approx$ 22, 22.9 , and 23.8.

The probability of having one X-ray source in the GRB error box is 0.16. This probability has been computed using the local number of sources detected above a 5σ level within the ROSAT HRI 30'x30' field of view. This probability is consistent with the ROSAT logN-logS relation derived by Hasinger et al. (1993, 1994) for a 5σ detection level of 5×10^{-14}erg.cm^{-2}.s^{-1} in our observation. Given the presence of 2 sources in the error box it is even more difficult to associate any of them with the GRB source. However we note that object #1 is variable, at least on a one year time scale, reinforcing the probability of a possible association with the GRB source. Optical observations are planned at ESO to determine the precise photometry of the sources, to derive their redshifts, and a possible association, as they could both belong to the same cluster of galaxies.

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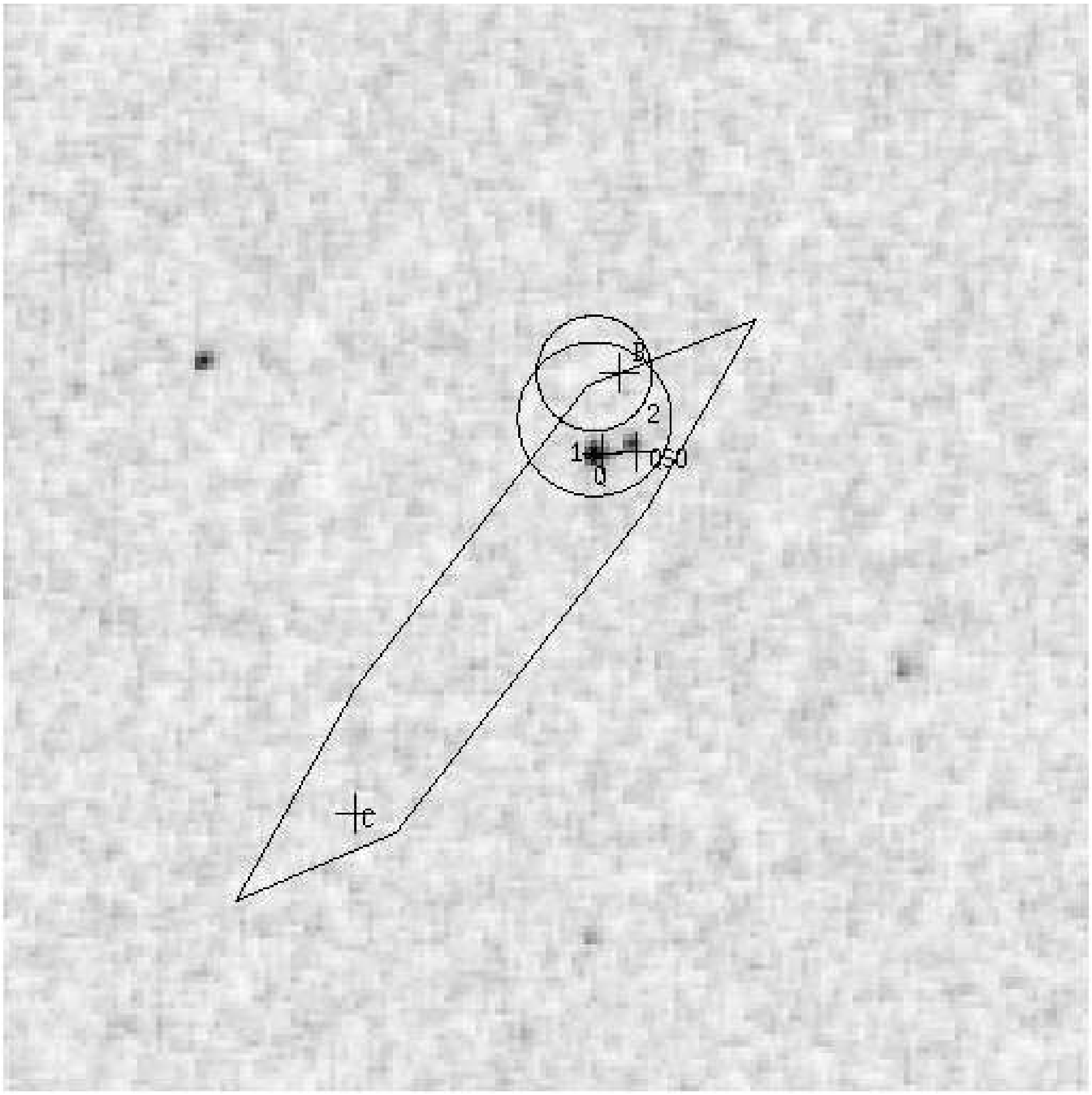
Table 1. Summary of the ROSAT HRI observations

Observation date	Jan. 10, 1995	Dec. 21, 1995 - Jan 11, 1996	
Object #	1	1	2
Object name	RX J0118.7-2835	RX J0118.7-2835	RX J0118.8-2835
Exposure time (seconds)	2481	40776	40776
Countrate (counts / kseconds)	6.6 ± 1.8	2.8 ± 0.3	1.2 ± 0.3
Signal to noise ratio	3.6	10	5.5
Flux[1]($\mathrm{erg.cm^{-2}.s^{-1}}$)	4.3×10^{-13}	2.2×10^{-13}	0.8×10^{-13}

[1]Assuming a power law spectrum of index 1.77 and a hydrogen column density of 1.76×10^{20} $\mathrm{cm^{-2}}$ (Hurley et al. 1996b, Dickey & Lockman 1990)

Fig. 1.— A 15 x 15 arcmin close-up of the ROSAT HRI image centered on the GRB 781119 error box, taken during the period December 21st, 1995 - January 11th, 1996. The error box of the GRB source is displayed (polygon), as well as the Einstein (small circle) and ASCA (large circle) error regions, the HRI sources #1 and #2, the radio objects B, C, and Q detected by Hjellming and Ewald (1981), and the position of the quasar source QSO 0116-288 (cross).

Fig. 2.— The optical content of the region the ROSAT HRI source #1 and #2. The image is the sum of several unfiltered CCD exposures from ESO



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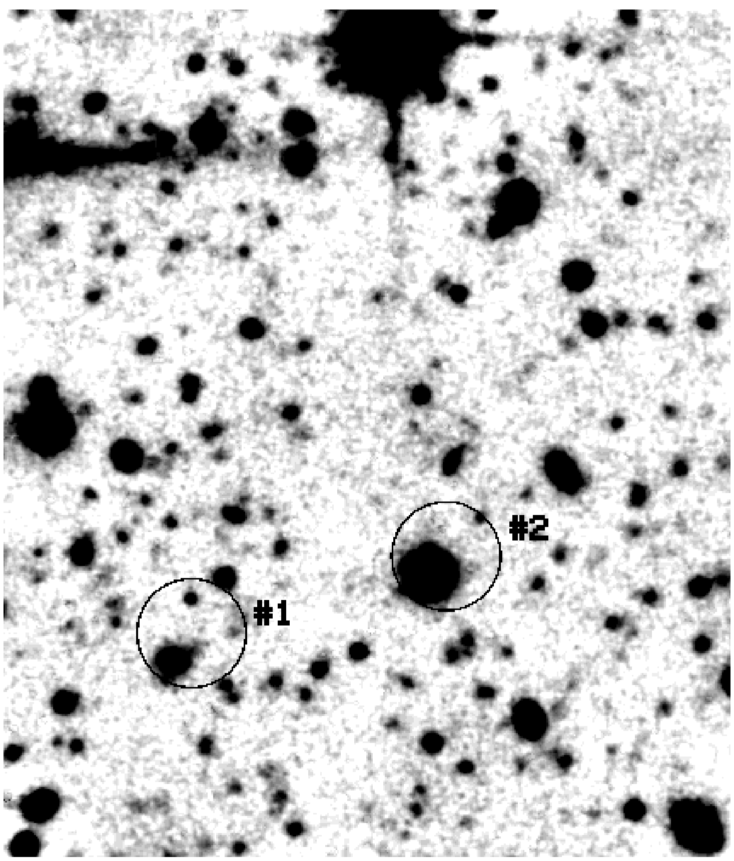
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